CLAIMS

I/We claim:

[c1]   1.   A multi-carrier wireless communication network, comprising:

one of multiple base stations, providing communication coverage to a cell, and configured to transmit cell-specific pilot subcarriers and common pilot subcarriers, wherein the cell-specific pilot subcarriers contain information concerning a specific cell, a specific base station, or both, and wherein the common pilot subcarriers contain.information common to a plurality of the cells, the base stations, or both; and

a mobile station capable of receiving the cell-specific pilot subcarriers and the common pilot subcarriers transmitted by the base station, and wherein the pilot subcarriers are employed in network operations.

[c2]   2.   The network of claim 1, wherein the common pilot subcarriers transmitted by different base stations are aligned in frequency index at transmission time.

[c3]   3.   The network of claim 1, wherein the receiver estimates a frequency of a received signal by $2\pi f_i \Delta t = \arg\{s_i^*(k)s_i(k+1)\} - \beta_i$, using common pilot subcarriers of a same frequency index i at different times t_k and t_{k+1}, provided that:

Δt << a coherence period of a communication channel;

$a_{i,m}(t_k) = c_i a_{i,m}(t_{k+1})$; and

$\varphi_{i,m}(t_k) = \varphi_{i,m}(t_{k+1}) + \beta_i$,

where:

$s_i(t_{k+1}) = e^{j2\pi f_i \Delta t} \sum_{m=1}^{M} a_{i,m}(t_{k+1}) e^{j\varphi_{i,m}(t_{k+1})}$ represents the received signal;

$c_i > 0$ and $-\pi \le \beta_i \le \pi$ are predetermined constants for all cells

m;

$\Delta t = t_{k+1} - t_k$;

s_i is the received signal in a pth cell, at time t_k; and

$a_{i,m}(t_k)$ and $\varphi_{i,m}(t_k)$ denote signal amplitude and phase, associated with

the ith subcarrier from the base station of the mth cell.

[c4]   4.   The network of claim 1, wherein the receiver computes a

frequency difference, Δf, of two common pilot subcarriers, transmitted at the same

time t_k but of different frequency indices i and n, of a received by

$2\pi\Delta f T_s(t_k) = \arg\{s_i^*(t_k)s_n(t_k)\} - \gamma(t_k)$, provided that:

Δf << a coherence bandwidth of a communication channel;

$a_{i,m}(t_k) = c(t_k)a_{n,m}(t_k)$; and

$\varphi_{i,m}(t_k) = \varphi_{n,m}(t_k) + \gamma(t_k)$,

where:

$$s_n(t_k) = e^{j 2\pi\Delta f T_s(t_k)} \sum_{m=1}^{M} a_{n,m}(t_k)e^{j\varphi_{n,m}(t_k)}$$ represents the received signal;

$c(t_k) > 0$ and $-\pi \le \gamma(t_k) \le \pi$ are predetermined constants for all

cells m;

$\Delta f = f_n - f_i$ and T_s denotes a sampling period;

s_i is the received signal in a pth cell, at time t_k; and

$a_{i,m}(t_k)$ and $\varphi_{i,m}(t_k)$ denote signal amplitude and phase, associated with

the ith subcarrier from the base station of the mth cell.

[c5]   5.   The network of claim 1, wherein phase diversity is achieved by

the base station adding a random phase $(\vartheta_{i,m})$ to a ith subcarrier such that:

$\varphi_{i,m}(t_k) = \varphi_{i,m}(t_k) + \vartheta_{i,m}$ and $\varphi_{i,m}(t_{k+1}) = \varphi_{i,m}(t_{k+1}) + \vartheta_{i,m}$,

where:

$\vartheta_{i,m}$ is different for each cell;

$$\varphi_{l,m}(t_k) = \varphi_{l,m}(t_{k+1}) + \beta_l, \quad \text{for all values of } m;$$

$-\pi \le \beta_i \le \pi$ is a predetermined constant for all cells m; and

$\varphi_{i,m}(t_k)$ denotes phase at time t_k, associated with an ith subcarrier from the base station of the mth cell.

[c6]   6.   The network of claim 1, wherein the base station is configured to apply power control to the pilot subcarriers by adjusting the power of the pilot subcarriers individually or in subgroups comprising a plurality of pilot subcarriers.

[c7]   7.   The network of claim 1, wherein each of the multiple base stations include multiple antennas within an individual sector and employ multiple transmission branches connected to different antennas, and wherein for frequency estimation the common pilot subcarriers for each transmission branch are generated such that:

$$a_{i,m}(t_k) = c_i a_{i,m}(t_{k+1}) \quad \text{and} \quad \varphi_{i,m}(t_k) = \varphi_{i,m}(t_{k+1}) + \beta_i,$$

where:

   $c_i > 0$ and $-\pi \le \beta_i \le \pi$ are predetermined constants for all cells m; and

   $a_{i,m}(t_k)$ and $\varphi_{i,m}(t_k)$ denote signal amplitude and phase at time t_k, associated with an ith subcarrier from a base station of the mth cell.

[c8]   8.   The network of claim 1, wherein each of the multiple base stations include multiple antennas within an individual sector and employ multiple transmission branches connected to different antennas, and wherein for timing estimation the common pilot subcarriers for each transmission branch are generated such that:

$$a_{i,m}(t_k) = c(t_k)a_{n,m}(t_k) \quad \text{and} \quad \varphi_{i,m}(t_k) = \varphi_{n,m}(t_k) + \gamma(t_k),$$

where:

$c(t_k) > 0$ and $-\pi \le \gamma(t_k) \le \pi$ are predetermined constants for all

cells m; and

$a_{i,m}(t_k)$ and $\varphi_{i,m}(t_k)$ denote signal amplitude and phase at time t_k,

associated with an ith subcarrier from a base station of the

m^{th} cell.

[c9]   9.   The network of claim 1, wherein both the cell-specific and common pilot subcarriers are used jointly in a process based on information theoretic criteria.

[c10]   10.   The network of claim 1, wherein the network operations are frequency synchronization and channel estimation.

[c11]   11.   The network of claim 1, wherein a microprocessor computes attributes of the pilot subcarriers, specified by their requirements, and inserts them into a frequency sequence contained in an electronic memory.

[c12]   12.   The network of claim 1, wherein a set of base stations within the network transmit, along with both cell-specific pilot subcarriers and common pilot subcarriers, cell-specific data subcarriers in which data information concerning a specific cell is embedded and common data subcarriers in which data information common to this set of cells in the network is embedded, and wherein a receiver within the network determines channel coefficients based on cell-specific pilot subcarriers and applies the channel coefficients to cell-specific data subcarriers to compensate for channel effects and to recover cell-specific data information and determines composite channel coefficients based on common pilot subcarriers and applies the composite channel coefficients to common data subcarriers to compensate for channel effects and to recover common data information.

[c13]   13.   A method of mitigating pilot signal degradation in a multi-carrier wireless communication network of cells, base stations, and mobile stations, the method comprising:

generating cell-specific pilot subcarriers at the base station, for performing network operations, wherein the cell-specific pilot subcarriers include information concerning a specific cell, a specific base station, or both;

inserting the generated cell-specific pilot subcarriers into predetermined frequency locations in a base station signal;

generating common pilot subcarriers at the base station, for performing network operations, wherein the common pilot subcarriers include information common to at least multiple cells, base stations, or both;

inserting the generated common pilot subcarriers into predetermined frequency locations in the base station signal; and

transmitting the base station signal.

[c14]   14.   The method of claim 13, wherein the common pilot subcarriers transmitted by different base stations are aligned in frequency index at transmission time.

[c15]   15.   The method of claim 13, wherein the base station transmitted signals are received by a mobile station, and wherein a frequency of the received base station signal is estimated using common pilot subcarriers of a same frequency index generated at a first and a second time, provided that a time difference between the first and the second time is significantly shorter than a coherence period of communication channel and that a signal amplitude associated with the frequency index from a cell, generated at the first time, is a predetermined multiple of the signal amplitude associated with the frequency index from that cell, generated at the second time, and that a phase associated with the same frequency index subcarrier from a cell, generated at the first time, is within ±180° of the phase

associated with the same frequency index subcarrier from that cell, generated at the second time.

[c16]   16.   The method of claim 13, wherein the network operations are frequency synchronization and channel estimation.

[c17]   17.   The method of claim 13, wherein phase diversity is achieved by adding a random phase to a subcarrier phase to prevent signal degradation, where the added phase is different for each cell, or wherein phase diversity is achieved by adding a random delay time duration, either in baseband or RF, to time-domain signals.

[c18]   18.   The method of claim 13, wherein signal power of the pilot subcarriers are controlled by adjusting their power individually or in subgroups comprising a plurality of pilot subcarriers.

[c19]   19.   The method of claim 13, wherein multiple antennas are used within an individual sector and multiple transmission branches are connected to different antennas, and wherein for frequency estimation common pilot subcarriers for each transmission branch are generated such that there is a predetermined relationship between signal amplitude and phases of the pilot subcarriers of a particular frequency index at specified times.

[c20]   20.   The method of claim 13, wherein multiple antennas are used within an individual sector and multiple transmission branches are connected to different antennas, and wherein for timing estimation common pilot subcarriers for each transmission branch are generated such that their amplitudes are predetermined multiples of the amplitudes generated by the rest of the base stations and their phases have predetermined differences with phases of those generated by the rest of the base stations.

[c21]   21.   The method of claim 13, wherein both the cell-specific and common pilot subcarriers are used jointly in a process based on information theoretic criteria.

[c22]   22.   The method of claim 13, wherein the base station transmitted signals are received by a mobile station.

[c23]   23.   A system for enhancing the performance of a wireless multi-carrier communication network of cells, base stations, and mobile stations by reducing the effects of signal degradation, the system comprising:

a means for generating cell-specific pilot subcarriers and common pilot subcarriers at the base stations, wherein the cell-specific pilot subcarriers include information concerning a specific cell, a specific base station, or both and the common pilot subcarriers include information common to at least a plurality of the cells, base stations, or both;

a means for inserting generated cell-specific pilot subcarriers and common pilot subcarriers into predetermined frequency locations in base station signals; and

a means for transmitting the base station signals.

[c24]   24.   The system of claim 23 further comprising a means for receiving the base station transmitted signals by a mobile station.

[c25]   25.   The system of claim 23 further comprising a means for utilizing the received pilot subcarriers for performing frequency synchronization, channel estimation, and network operations.

[c26]   26.   A method of mitigating pilot signal degradation in a multi-carrier wireless communication network of cells, base stations, and mobile stations, the method comprising receiving base station transmitted signals wherein received cell-specific pilot subcarrier signals containing information concerning a specific cell, a

specific base station, or both, and/or common pilot subcarrier signals containing information common to a plurality of the cells, the base stations, or both, are utilized for performing network operations.

[c27]   27.   The method of claim 26, wherein a frequency of the received base station signal is estimated using common pilot subcarriers of a same frequency index generated at a first and a second time, provided that a time difference between the first and the second time is significantly shorter than a coherence period of communication channel and that a signal amplitude associated with the frequency index from a cell, generated at the first time, is a predetermined multiple of the signal amplitude associated with the frequency index from that cell, generated at the second time, and that a phase associated with the same frequency index subcarrier from a cell, generated at the first time, is within ±180° of the phase associated with the same frequency index subcarrier from that cell, generated at the second time.

[c28]   28.   The method of claim 26, wherein a mobile station receives the base station transmitted signals.

[c29]   29.   The method of claim 26 further comprising a means for performing network operations, wherein the network operations are frequency synchronization and channel estimation.

[c30]   30.   A multi-carrier wireless communication network, comprising:
        one of multiple base stations, providing communication coverage to a cell, and configured to transmit cell-specific pilot subcarriers, common pilot subcarriers, cell-specific data subcarriers, and common data subcarriers, wherein the cell-specific pilot subcarriers contain information concerning a specific cell, a specific base station, or both, and wherein the common pilot subcarriers contain information common to a plurality of the cells, the base stations, or both, and wherein data information

concerning a specific cell is embedded in the cell-specific data
subcarriers, and wherein data information common to a plurality
of cells in the network is embedded in the common data
subcarriers; and

wherein the pilot subcarriers are employed in network operations and
wherein a receiver within the network determines channel
coefficients based on cell-specific pilot subcarriers and applies
the channel coefficients to cell-specific data subcarriers to
compensate for channel effects and to recover cell-specific data
information, and determines composite channel coefficients
based on common pilot subcarriers and applies the composite
channel coefficients to the set of common data subcarriers to
compensate for channel effects and to recover common data
information.